

Hydrocarbon Rocket Technology Impact Forecasting

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Ever since the Apollo program ended, the development of launch propulsion systems in the US has fallen drastically, with only two new booster engine developments, the SSME and the RS-68, occurring in the past few decades.¹ In recent years, however, there has been an increased interest in pursuing more effective launch propulsion technologies in the U.S., exemplified by the NASA Office of the Chief Technologist's inclusion of Launch Propulsion Systems as the first technological area in the Space Technology Roadmaps². One area of particular interest to both government agencies and commercial entities has been the development of hydrocarbon engines; NASA and the Air Force Research Lab³ have expressed interest in the use of hydrocarbon fuels for their respective SLS Booster and Reusable Booster System concepts, and two major commercially-developed launch vehicles—SpaceX's Falcon 9 and Orbital Sciences' Antares—feature engines that use RP-1 kerosene fuel.

Compared to engines powered by liquid hydrogen, hydrocarbon-fueled engines have a greater propellant density (usually resulting in a lighter overall engine), produce greater propulsive force, possess easier fuel handling and loading, and for reusable vehicle concepts can provide a shorter turnaround time between launches. These benefits suggest that a hydrocarbon-fueled launch vehicle would allow for a cheap and frequent means of access to space.¹ However, the time and money required for the development of a new engine still presents a major challenge. Long and costly design, development, testing and evaluation (DDT&E) programs underscore the importance of identifying critical technologies and prioritizing investment efforts. Trade studies must be performed on engine concepts examining the affordability, operability, and reliability of each concept, and quantifying the impacts of proposed technologies. These studies can be performed through use of the Technology Impact Forecasting (TIF) method.

The Technology Impact Forecasting method is a normative forecasting technique that allows the designer to quantify the effects of adding new technologies on a given design. This method can be used to assess and identify the necessary technological improvements needed to close the gap that exists between the current design and one that satisfies all constraints imposed on the design. The TIF methodology allows for more design knowledge to be brought to the earlier phases of the design process, making use of tools such as Quality Function Deployments, Morphological Matrices, Response Surface Methodology, and Monte Carlo Simulations.² This increased knowledge allows for more informed decisions to be made earlier in the design process, resulting in shortened design cycle time. This paper will investigate applying the TIF method, which has been widely used in aircraft applications, to the conceptual design of a hydrocarbon rocket engine.

In order to reinstate a manned presence in space, the U.S. must develop an affordable and sustainable launch capability. Hydrocarbon-fueled rockets have drawn interest from numerous major government and commercial entities because they offer a low-cost heavy-lift option that would allow for frequent launches¹. However, the development of effective new hydrocarbon rockets would likely require new technologies in order to overcome certain design constraints. The use of advanced design methods, such as the TIF method, enables the designer to identify key areas in need of improvement, allowing one to dial in a proposed technology and assess its impact on the system. Through analyses such as this one, a conceptual design for a hydrocarbon-fueled vehicle that meets all imposed requirements can be achieved.

References

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